



ASTM INTERNATIONAL  
Selected Technical Papers

# Environmentally Considerate Lubricants

STP 1575  
Editor:  
In-Sik Rhee



**SELECTED TECHNICAL PAPERS**  
**STP1575**

---

Editor: In-Sik Rhee

# Environmentally Considerate Lubricants

---

ASTM Stock #STP1575

**Library of Congress Cataloging-in-Publication Data**

Environmentally considerate lubricants / [compiled by] In-Sik Rhee.

pages cm -- (Selected technical papers ; STP 1575)

"ASTM Stock #STP1575"

Includes bibliographical references and index.

ISBN 978-0-8031-7595-2 (alk. paper)

1. Lubrication and lubricants. 2. Green chemistry. I. Rhee, In-Sik.

TJ1077.E68 2014

621.8'9--dc23

2014044155

Copyright © 2014 ASTM INTERNATIONAL, West Conshohocken, PA. All rights reserved. This material may not be reproduced or copied, in whole or in part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of the publisher.

**Photocopy Rights**

Authorization to photocopy items for internal, personal, or educational classroom use, or the internal, personal, or educational classroom use of specific clients, is granted by ASTM International provided that the appropriate fee is paid to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, Tel: (978) 646-2600; <http://www.copyright.com/>

The Society is not responsible, as a body, for the statements and opinions expressed in this publication. ASTM International does not endorse any products represented in this publication.

**Peer Review Policy**

Each paper published in this volume was evaluated by two peer reviewers and at least one editor. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM International Committee on Publications.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of the peer reviewers. In keeping with long-standing publication practices, ASTM International maintains the anonymity of the peer reviewers. The ASTM International Committee on Publications acknowledges with appreciation their dedication and contribution of time and effort on behalf of ASTM International.

**Citation of Papers**

When citing papers from this publication, the appropriate citation includes the paper authors, "paper title", STP title, STP number, book editor(s), page range, Paper doi, ASTM International, West Conshohocken, PA, year listed in the footnote of the paper. A citation is provided on page one of each paper.

## Foreword

This compilation of *Selected Technical Papers*, STP1575, *Environmentally Considerate Lubricants* contains 9 papers presented at a symposium with the same name held December 9, 2013 in Tampa, FL, USA. The symposium was sponsored by ASTM International Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and Subcommittee D02.12 on Environmental Standards for Lubricants.

The Symposium Chairman and STP Editor is Dr. In-Sik Rhee, United States Army TARDEC, Warren, MI, USA.



# Contents

<b>Overview</b>	vii
<b>Environmentally Friendly Lubricant-Development Programs at USDA</b> G. Biresaw	1
<b>Understanding Component Requirements for Formulating High Performance Environmentally Acceptable Greases</b> G. Fish, P. Robinson, and N. McSkimming	24
<b>Evaluation of Different Readily Biodegradable Base Fluids in a Multi-Purpose Grease-Development Project</b> M. Bailey, B. Kusak, M. Almeter, and J. Smahol	36
<b>Benchmark of Alternative Lubricants for Hydraulic Systems</b> T. Nakase, M. Woydt, S. Kato, and S. Sasaki	52
<b>Formulation Process for Environmentally Considerate Lubricants</b> J. Sander	76
<b>A Sustainable Lubricant Solution for Applications in Environmentally Sensitive Areas</b> P. Lämmle, M. Ruch, and C. Cheval	93
<b>Study of Wear Properties of Environmentally Friendly Lubricants for Gearing Applications as a Function of Film Thickness Transition</b> J. T. Galary	105
<b>Relative Humidity Sensors and the Solubility of Water in Lubricants</b> M. M. Krause and P. W. Michael	131
<b>Development of a New Toxicity Test Method Using a Bio-Dipstick</b> I.-S. Rhee	147



## Overview

In recent years, there has been an increasing interest in Environmentally Acceptable (EA) or Environmentally Considerate (EC) Lubricants, especially among vessel, agricultural, construction, forestry, lumber, and mining industries where involuntary or accidental fluid leakage or spillage is detrimental to the environment. Another good reason to use EA lubricants is to find an alternative source of lubricants from the agricultural feed stocks and to reduce the consumption of petroleum crude oil. Currently, the biobased lubricants are considered as EA lubricants due to their environmental properties such as a high biodegradability, low toxicity, and no bioaccumulation. The biobased lubricant is currently formulated with oils extracted from renewable resources such as plants, crops, trees, or animals. These types of fluids are considered less toxic and more biodegradable than conventional petroleum based oils. The U. S. Department of Agriculture's (USDA) biobased product guideline also defines exactly what products and how much concentration of renewable product associated with final product would be considered as a biobased product. Recently, the U. S. Environmental Protection Agency (EPA) has also defined the EA lubricants based on the environmental properties and issued the Vessel General Permit (VGP) guide which requires the use of EA lubricants for all commercial vessels longer than 79 feet operated within three nautical miles of U. S. coastlines and in the Great Lakes. In response to the demand of EA lubricants, many oil companies have formulated EA lubricants for limited applications. To explore further this developing technology, research has already been or is being conducted in the broad science field using biobased oils.

ASTM D02.12 Subcommittee on Environmental Standards of Lubricants has a responsibility to promote the knowledge and the development of standards to measure environmental persistence of lubricants (e.g., biodegradation, ecotoxicity and bioaccumulation). To hold a forum for discussions related to current trends for EA lubricants, the Subcommittee D02.12 initiated the *Second Environment Symposium on Environmentally Considerate Lubricants* which was held on December 9, 2013 in Tampa, Florida. The purpose of this symposium was to provide details on current research efforts to advance the use of biobased and other environmentally considerate lubricants, and to develop new and improved environment test methods. Eleven symposium papers were presented on the various topics related to the fundamentals of biobased lubricants, industrial trends, applications, new test methods, and environmental policies. All presentations were very innovated and well-received from more than 100 attendees. Nine papers among them were selected for presenting in



the STP (Selected Technical Papers) after being peer-reviewed. These papers are presented here.

Finally, the Editor would like to acknowledge that this STP is a product of tremendous diligent efforts of many people. In particular, the Editor would like to thank ASTM D02.12 symposium organizing committee, all of the authors, paper reviewers and session chairs who devoted their valuable time for this endeavor. Special thanks are due to Mary Mikolajewski, David Bradley, Suze Reilly, and Heather Blasco for their enduring support, constructive feedbacks, and timely assistance.

Dr. In-Sik Rhee  
Symposium Chairman  
U. S. Army Tank, Automotive Research  
Development and Engineering Center  
Warren, MI, USA

ASTM INTERNATIONAL  
Helping our world work better

ISBN: 978-0-8031-7595-2  
Stock #: STP1575

[www.astm.org](http://www.astm.org)